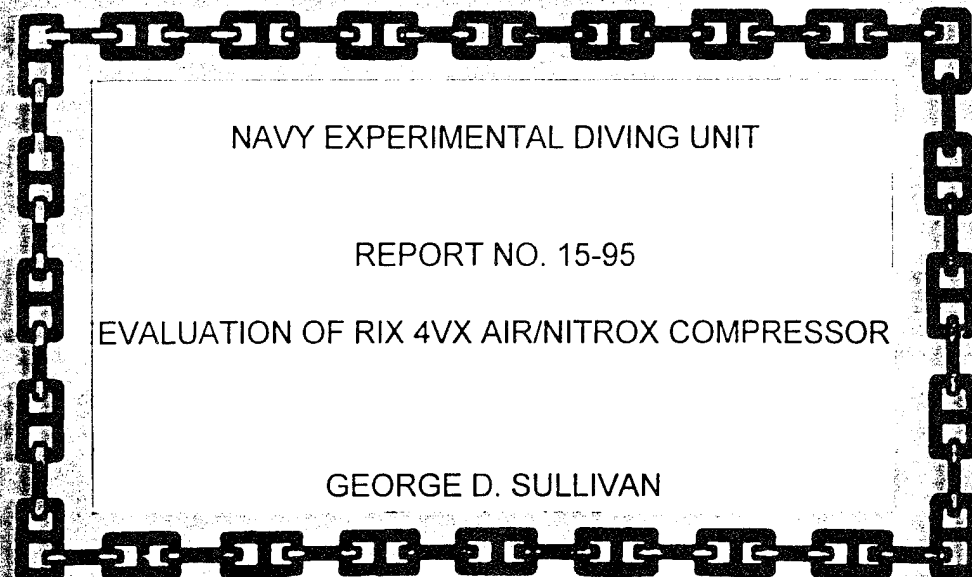




NAVY EXPERIMENTAL DIVING UNIT

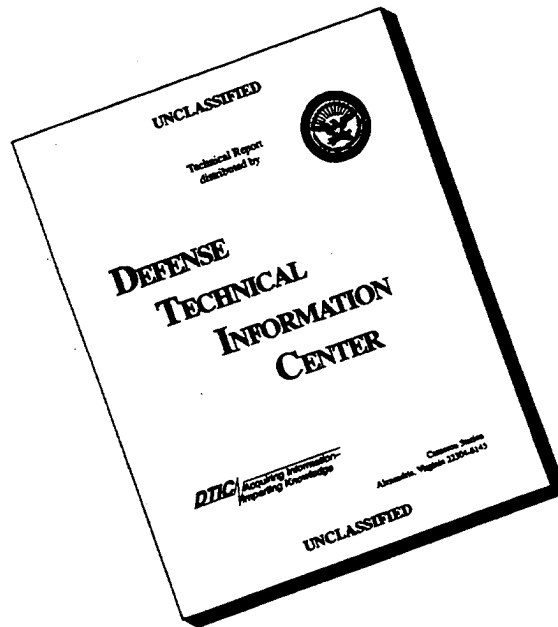


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NAVY EXPERIMENTAL DIVING UNIT

321 BULLFINCH ROAD
PANAMA CITY, FLORIDA 32407-7015

NAVSEA TASK 95-18

IN REPLY REFER TO:

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 15-95

EVALUATION OF RIX 4VX AIR/NITROX COMPRESSOR

GEORGE D. SULLIVAN

December 1995

Approved for public release; distribution unlimited

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In response to reference (1), Navy Experimental Diving Unit (NEDU) tested the Rix 4VX Air/Nitrox Compressor from 25 Oct 95 to 27 Nov 95. The purpose of this test was to determine if the equipment was suitable for the ANU List. The RIX 4VX Air/Nitrox Compressor delivers acceptable breathing air at a capacity which meets the manufacturer's specification. It is recommended for inclusion on the ANU List.				
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I. INTRODUCTION

In response to NAVSEA tasking¹, Navy Experimental Diving Unit (NEDU) evaluated a RIX 4VX AIR/NITROX COMPRESSOR, MODEL 4VX4B-23.3B.² The test took place at NEDU from 25 October through 27 November 1995. The purpose was to:

A. Determine if the compressor system provides compressed air at the required pressures, flow rates, quality and cleanliness required by the U.S. Navy³.

B. Determine the adequacy of the manufacturer's information, instructions and guidance for the safe operation and overall management of the compressor.

C. Ensure that the compressor system discharged clean breathing air required by the U.S. Navy³.

II. EQUIPMENT DESCRIPTION

The RIX 4VX AIR/NITROX COMPRESSOR, MODEL 4VX4B-23.3B is built in a four stage, four cylinder, "vee" configuration. The reciprocating, single acting, crosshead design features oil free operation through the use of self-lubricating piston rings constructed of TFE materials operating inside stainless steel cylinder bores. It is powered by a 25 HP, 3 Phase, electric motor (rated at either 208/380V, 50Hz, 3000 RPM or 230/460V, 60 Hz 3600 RPM) through a V-belt drive. All four stages feature oil-free compression which allows compression of nitrogen-oxygen mixtures of up to 40 percent oxygen to 5000 psig and compression of air to 5000 psig. Oil free compression eliminates the need for an elaborate purification system. The crank case components are oil pressure fed and the crank case is isolated from the cylinders by an enclosed vented void area.

The RIX compressor unit consists of a compressor block and a drive motor, both mounted on a slide base to provide a means of adjusting the drive belts (Figure 1 and 2). The drive unit for this test was a 460 Volt motor operating at 3600 RPM. Rotational torque is transferred to the compressor by a single banded-belt. Electric motors purchased for use with this compressor must comply with Navy standards for sealed insulated systems⁴.

Moisture separators (water traps) remove water after each stage (see Figure 3.) A cam timer actuates solenoid valves, which automatically drain the separators every fifteen minutes. The cam timer is manually adjustable and is located beneath the heat exchangers in the junction box mounted to the bedplate.

The compressor is air cooled by a 3/4 HP, hazardous duty design, electrically driven fan. Four finned tube heat exchangers cool the gas after compression in each successive stage. The cooling air is pulled through the heat exchangers by the fan, then split into separate streams and directed over the cooling fins of each cylinder head and compression cylinder.

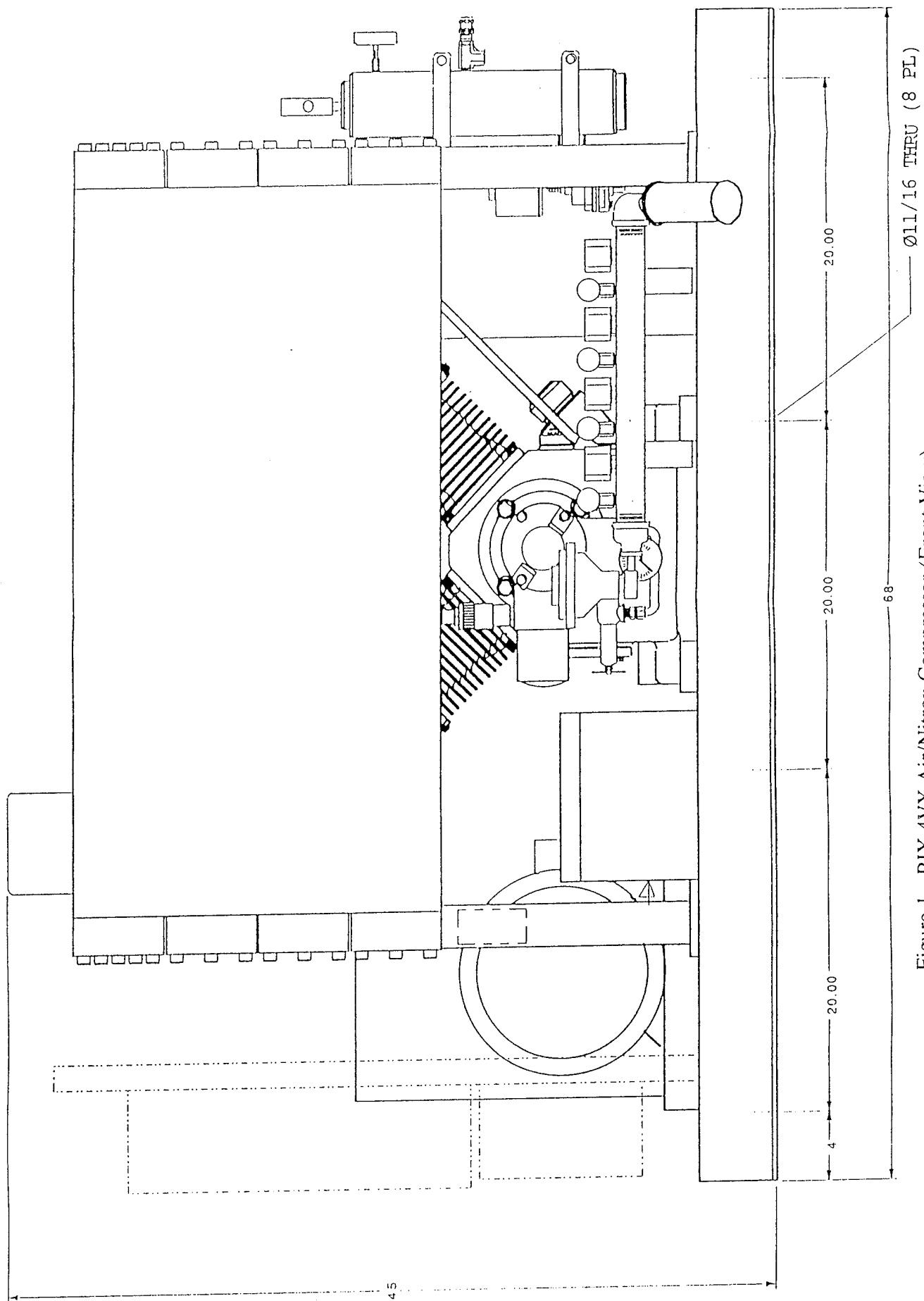


Figure 1. RIX 4VX Air/Nitrox Compressor (Front View)

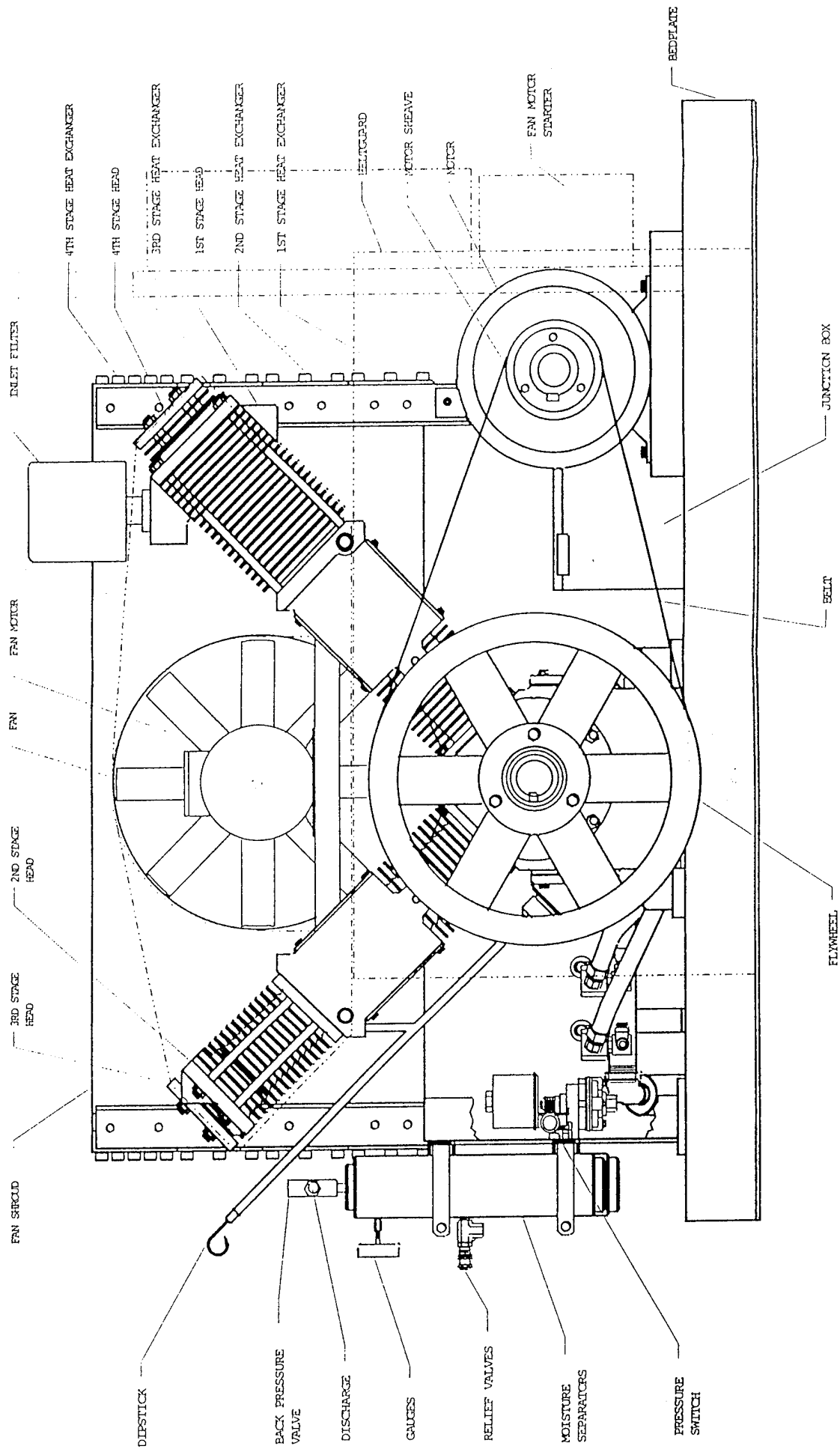


Figure 2. RIX 4VX Air/Nitrox Compressor (Rear View)

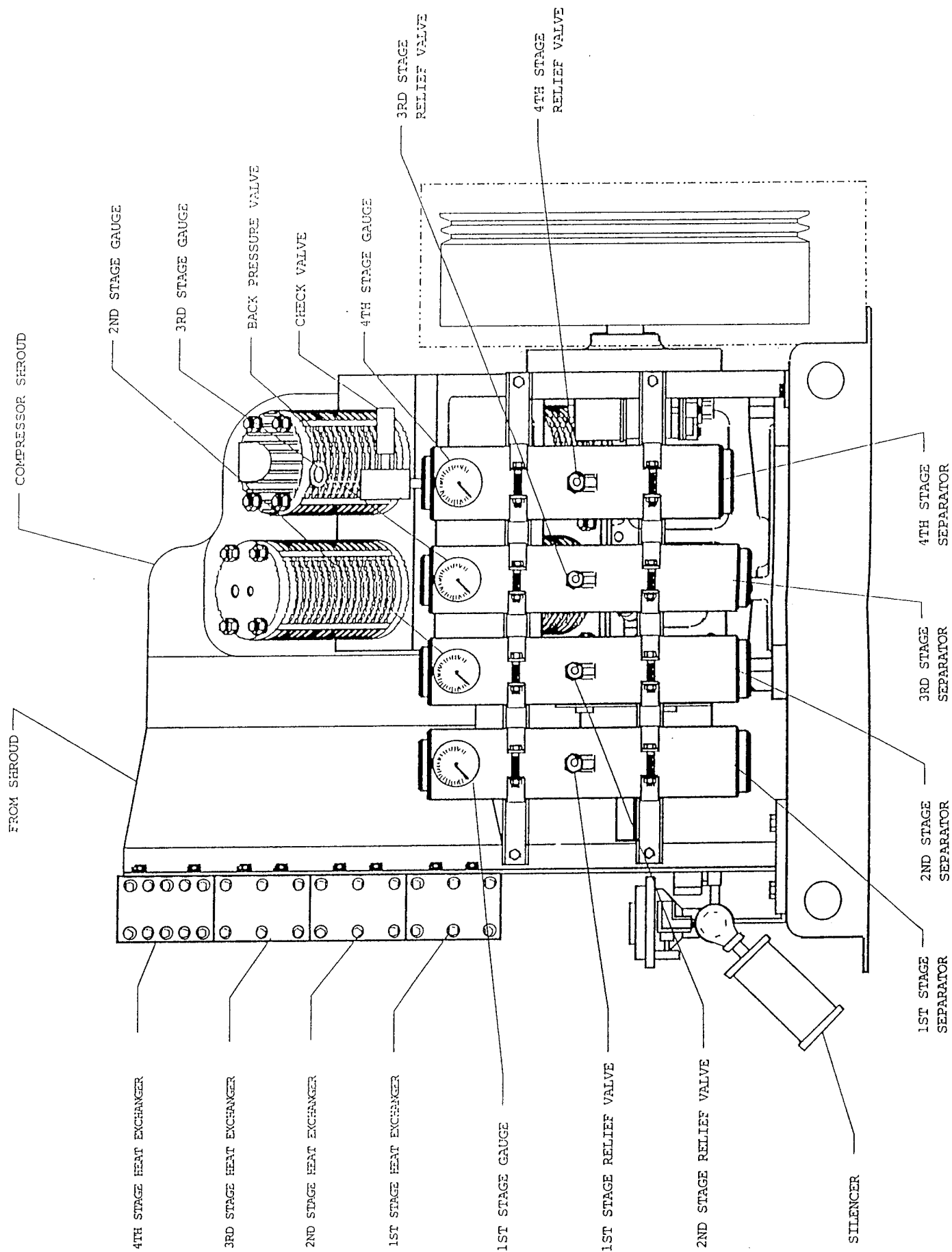


Figure 3. RIX 4VX Air/Nitrox Compressor (Side View)

Built-in safety features automatically shut down the compressor if excessive temperatures or pressures are reached in the 4th stage discharge line. A pressure switch is connected to the 4th stage discharge downstream from the check valve. A temperature switch bulb is strapped to the 4th stage discharge line upstream of the 4th stage heat exchanger. A low oil pressure switch will shut down the compressor if the pressure drops below the set pressure. Oil, interstage, and discharge pressures are indicated by gauges.

III. TEST PROCEDURE

There are various methods of testing compressor capacities, stability, and reliability. For this compressor evaluation², NEDU chose to run two separate tests of 50 hours each: one using nitrogen to evaluate the unit as a nitrox compressor, and one using air to evaluate the unit as an air compressor.

A. NITROGEN TEST

The compressor and all ancillary equipment were received and set up as per manufacturer's instructions. Test setup is shown in Figure 4. A Cole Palmer Model 8502-14 temperature monitor and Yellow Springs Instruments 700 Series thermistor probes were attached for measuring compressor discharge and ambient temperatures.

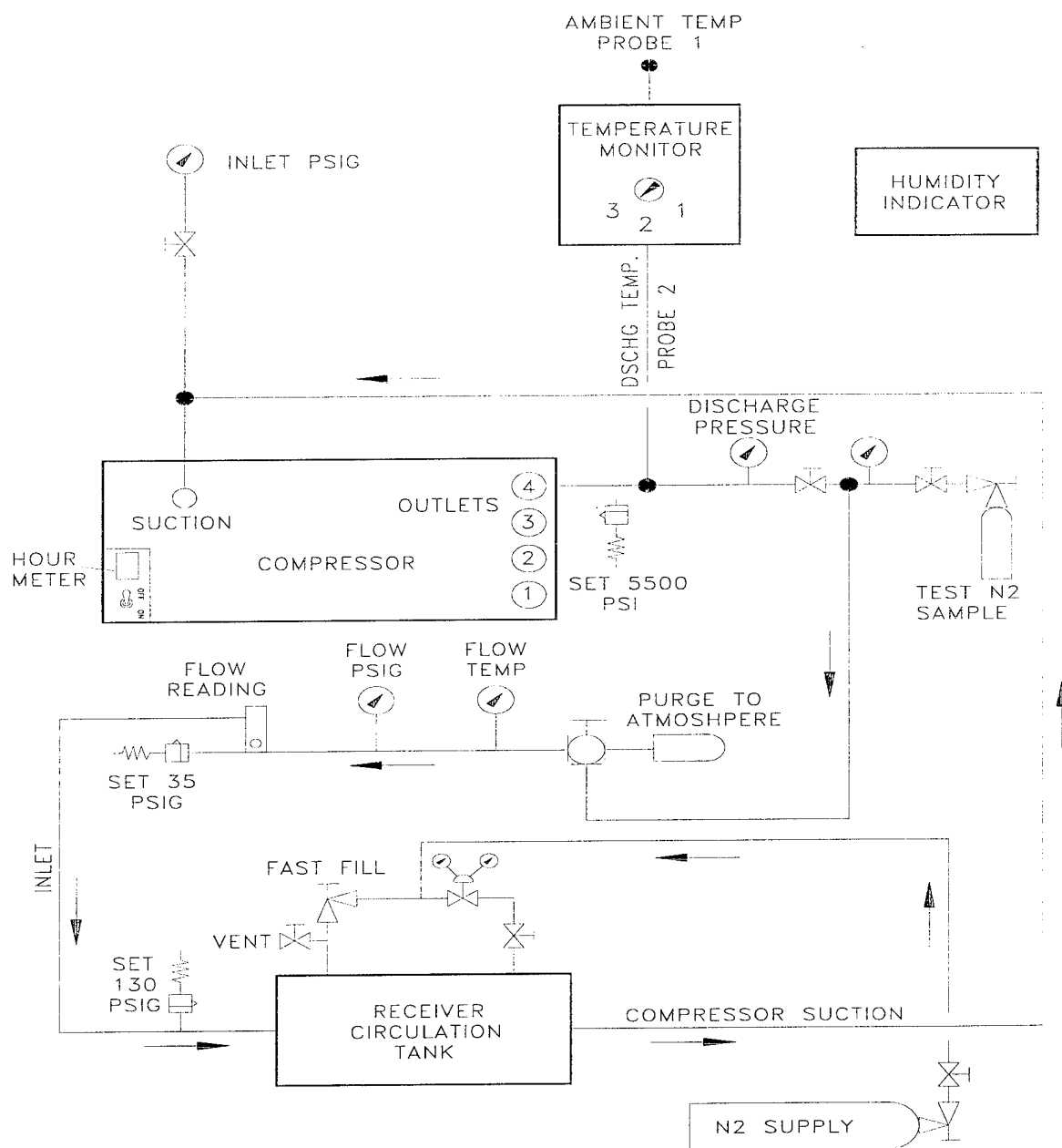
At the beginning of each test day, the compressor and volume tank were purged using nitrogen. Once the system was fully charged, the nitrogen source was secured. The nitrogen was then circulated in a closed loop configuration (round-robin) for the duration of the test day. Gas samples were tested after 1, 25, and 50 hours of testing. Results are presented in Appendix B.

Appendix A shows the recorded data from the Test Log. The unit was operated in an exterior work area, open to ambient temperature and humidity. The testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

Example computations (standard cubic feet per minute (SCFM)) for the nitrogen test are shown below. A flow reading of 20 cfm at 13 psig and 32°F were calculated as follows:

$$\text{SCFM} = (\text{Flow Reading}) \times \sqrt{\frac{\text{Flow psig} + 14.7}{14.7}} \times \sqrt{\frac{460 + 70}{460 + \text{Flow Temp } ^\circ\text{F}}} \times \sqrt{\frac{28.975}{28}}$$

$$20 \times \sqrt{\frac{13 + 14.7}{14.7}} \times \sqrt{\frac{460 + 70}{460 + 32}} \times \sqrt{\frac{28.975}{28}} = 28.9 \text{ scfm}$$



LEGEND



FIGURE 4. NEDU TEST NO. 95-14, NITROX CONFIGURATION

B. AIR TEST

The compressor and all ancillary equipment were set up as per manufacturer's instructions. Test setup is shown in Figure 5. A Cole Palmer Model 8502-14 temperature monitor and Yellow Springs Instruments 700 Series thermistor probes were attached for measuring compressor discharge, ambient temperatures, and storage cylinder air temperature.

The compressor was operated for extended periods charging an 89.2 liter (3.15 cuft) cylinder from 0 bars to 345 bars (0 to 5,000 psig). Total test time was 50 hours. Air samples were tested after 1, 25, and 50 hours of testing. Results presented in Appendix B.

Appendix A shows the recorded data from the Test Log. The unit was operated in an exterior work area, open to ambient temperature and humidity. The testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

Example computations for the air test are shown below.

A 3.15 cubic foot cylinder charged to 4725 psig in 29 minutes. The temperature at the beginning of the charge was 63.1 degrees F and was 120 degrees F when the 4725 psig was recorded.

The temperature correction factor was calculated as follows:

$$\text{Temp. Corr. Factor} = \frac{T_1 + 460}{T_2 + 460} = \frac{63.1 + 460}{120 + 460} = \frac{523.1}{580.0} = .902$$

T_1 = Start Temperature °F

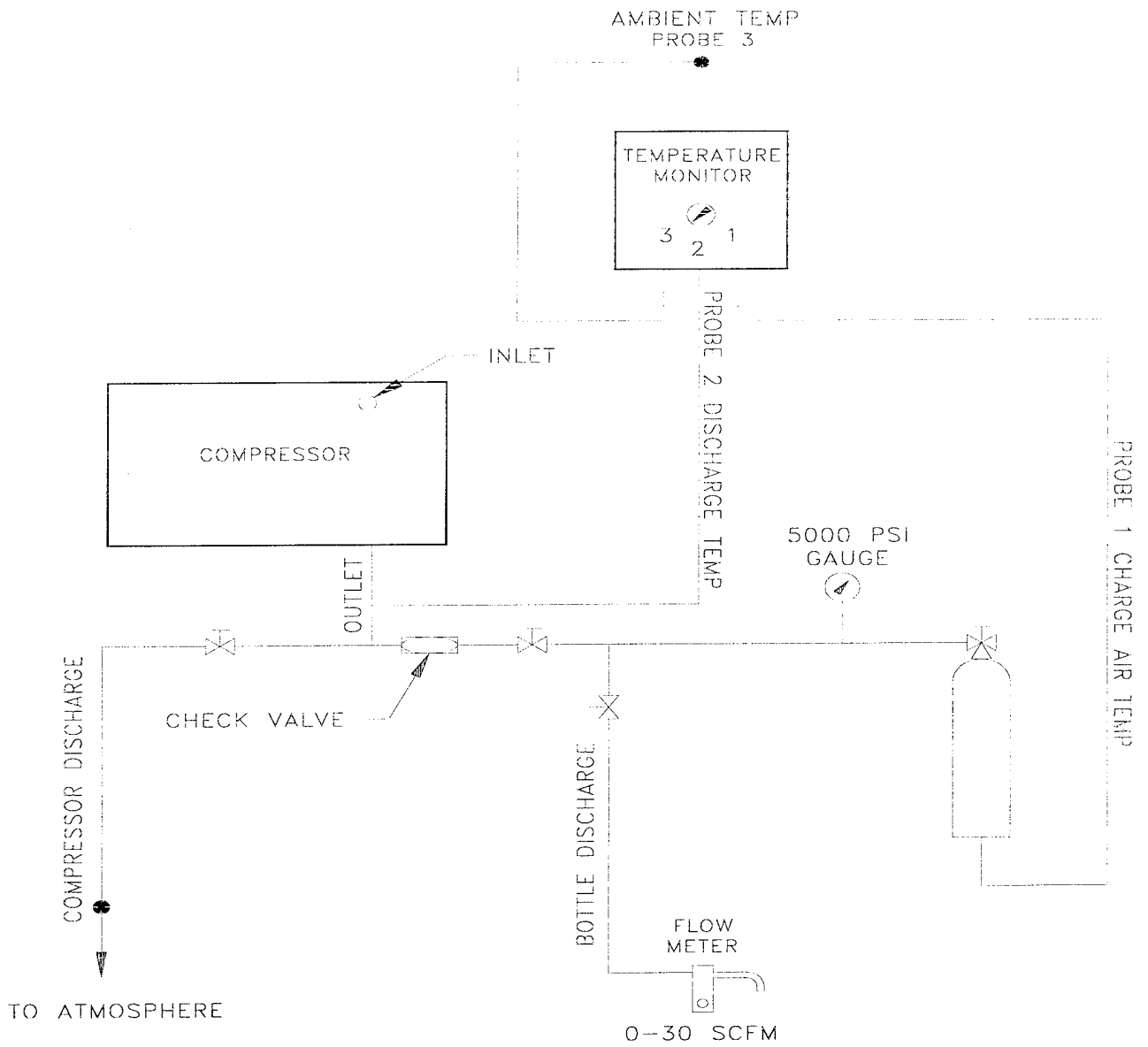
T_2 = End Temperature °F

The total volume (ATA X floodable volume) was calculated as follows:

$$\text{Total Volume} = \frac{\text{psig} + 14.7}{14.7} \times 3.15 \text{ ft.}^3 = \frac{4725 + 14.7}{14.7} \times 3.15 \text{ ft.}^3 = 1015.65 \text{ ft.}^3$$

Standard cubic feet per minute was calculated as follows:

$$\text{SCFM} = \frac{\text{Total Volume} \times \text{Temperature Correction Factor}}{\text{Fill Time}} = \frac{1015.65 \times .902}{29 \text{ min.}} = 31.6 \text{ scfm}$$



LEGEND



FIGURE 5. NEDU TEST NO. 95-14, AIR CONFIGURATION

IV. OBSERVATIONS/RECOMMENDATIONS

A. DELIVERY

Compressor capacity when using nitrogen was determined to be 818 liters per minute (28.9 SCFM) by calculating the average of the hourly flow rates recorded in Appendix A.

Compressor capacity when using air was determined to be 848 liters per minute (30.0 SCFM) by calculating the average of the charging times recorded in Appendix A.

B. SAMPLING

Gas samples were taken from the compressor purification system discharge at the 1st, 25th, and 50th hour of running time. The samples were sent to the Coastal System Station (CSS) Laboratory, Code 5130, for purity analysis. Analysis of air samples (listed in Appendix B) show that the compressor meets U. S. Navy requirements.

C. OIL LUBRICATION

Because oil lubrication is only needed for the crankcase components, no oil consumption was expected. The crankcase oil level was checked at the beginning and end of each day's testing. The compressor did not consume or leak any oil during either test. The oil used during the testing was SAE 30 weight motor oil.

D. MAINTENANCE

No scheduled maintenance was required during this test. The following unscheduled maintenance was performed:

26 October 1022	Hour meter repaired.
27 October 0920	Wire on electric power transformer repaired.
30 October 0920	Wire on electric power transformer repaired. Relief valve replaced.

Some minor malfunctions were encountered during the evaluation. These malfunctions were the failure of the hour meter, fourth stage relief valve and the controller transformer. The manufacturer has been informed and has made component changes to eliminate the causes in future compressors.

V. CONCLUSIONS & RECOMMENDATIONS

A. The RIX Model 4VX air/nitrox compressor delivers air which exceeds the U.S. Navy standards³ for purity. The compressor output averaged 818 liters per minute (28.9 SCFM) of nitrox, or 849 liters per minute (30.0 SCFM) of air, per Appendix A. This exceeds the manufacturer's specification of 27 SCFM.

B. The unit is sturdy, reliable, and readily maintained.

C. Based on the results of testing, the RIX Model 4VX air/nitrox compressor system is recommended for inclusion on the Authorized for Navy Use List⁵.

D. The vendor and NAVSEA should be contacted prior to purchase to ensure the unit meets the user's needs.

VI. REFERENCES

1. NAVSEA Task 95-18; Evaluation of RIX 40X Air/Nitrox Compressor. Naval Sea Systems Command, 1995
2. RIX Model 4VX Air/Nitrox Compressor Evaluation Test Plan 93.33 (Unmanned). Navy Experimental Diving Unit, June 1995, Limited Distribution
3. NAVSEA 0994-LP-001-9010 U.S. Navy Diving Manual, Vol 1, Rev. 3, Para 5.3.2. Air purity standards, and 6.7.2.1. Air Compressors
4. Department of Defense MIL-M-17060 E Amendment 1, Sealed Insulated Systems, (Service A Use). Navy specification for compressor power source
5. Naval Sea Systems Command NAVSEAINST 10560.2C Diving Equipment Authorized for U. S. Navy Use

NITROGEN TEST

TIME	METER HOURS	TEMP °F			AMBI HUMID %	CHARGED CYLINDER SIZE		CYLINDER CHARGING INFORMATION			INLET PSIG MAX: 2.5 MIN: 0	CYL FILL TIME	COMPRESSOR CYLINDER STAGES PSI				FLOW RDG	FLOW PSIG	SCFM (Calc)	OIL PRESS PSI	
		AMBI PROBE #1 MAX: 425 MIN: -10	COMP DSCHG PROBE #2 MAX: 70 MIN: -10	FLOW		RATED	CU FT	START TIME	END TIME	END PSI			1ST 45-55	2ND 225-275	3RD 900-1100	4TH 5000					
0840	Start																				
0940	I/O	79.7	45.5	32							2.5			44	240	1000	5000	20	13	28.99	38
1040	I/O	81.9	46	38							2.5			45	240	1000	5000	19.5	14	28.59	38
1140	I/O	84.9	53.8	40							2.5			45	240	1000	5000	20	13	28.75	36
1240	I/O	86.1	64.3	44							2.5			40	220	950	4000	20	14	29.15	36
1340	I/O	86.1	63.1	49							2.5			40	230	950	4000	20	14	29.01	36
1440	I/O	86.2	55.2	40							2.5			44	240	1000	5000	20	12	28.23	36
1540	I/O	85.4	53.2	40							2.5			44	240	1000	5000	20	14	29.27	36
1640	I/O	86.9	52.6	40							2.5			44	240	1000	5000	20	14	29.27	36

NOTES:
1. Oil full at startup and shutdown.
2. Hourmeter inoperable on startup I/O. Manufacturer is shipping a new one.

Appendix A-1

NITROGEN TEST

TIME	METER HOURS	TEMP °F			CHARGED CYLINDER SIZE		CYLINDER CHARGING INFORMATION			INLET PSIG MAX: 2.5 MIN: 0	CYL FILL TIME	COMPRESSOR CYLINDER STAGES PSI				FLOW RDG	FLOW PSIG	SCFM (Calc)	OIL PRESS PSI
		AMBI PROBE #1 MAX: 425	COMB DSCHG PROBE #2 MAX: 70	FLOW MAX: -10	RATED CU FT	START TIME	END TIME	END PSI	1ST 45-55			2ND 225-275	3RD 900-1100	4TH 5000					
0730	Start																		
0830	I/O	74.9	90.5	22	60							44	230	950	5000	1.95	12	28.03	38
0930	I/O	74.9	95.3	32	60							45	230	950	5000	19.5	12	27.75	36
1030	.4	81.0	101.2	32	57							45	230	950	5000	20	12	28.46	36
1130	1.4	89.4	104.8	38	57							45	230	950	5000	20	12	28.29	36
1230	2.4	87.8	105.3	40	63							45	240	1000	5000	20	13	28.75	38
1330	3.4	88.4	105.5	39	62							45	240	1000	5000	20	13	28.78	36
1430	4.4	88.9	104.9	40	63							45	240	1000	5000	20	13	28.75	36
1530	5.4	87.9	104.8	39	60							45	240	1000	5000	20	12	28.26	36

NOTES:

- Oil full at startup and shutdown.
- Hour meter was repaired at 1022. Meter was reading .4 upon installation.

NITROGEN TEST

[illegible]

1. Oil full at startup and shutdown.
2. Compressor shut down by operator at 0920. Could not stabilize discharge pressure to 5000 psi. Compressor began to clatter and pulsate struggling to keep running. Began troubleshooting. Operating vibration caused hard copper wire on electric power transformer to break, disconnecting control's power source to programmable controller and causing complete shutdown of power.
3. Fourth stage relief valve began to fail, opening at 4800 psi. Made adjustment to continue test.

RIX COMPRESSOR
4VX BREATHING AIR PACKAGE/230V
ACCEPTANCE TEST DATA

NITROGEN TEST

DATE: 30 October 1995

TIME	METER HOURS	TEMP °F			CHARGED CYLINDER SIZE			CYLINDER CHARGING INFORMATION			INLET PSIG	CYL FILL TIME	COMPRESSOR CYLINDER STAGES PSI				FLOW RDG	FLOW PSIG	SCFM (Calc)	OIL PRESS PSI
		AMBI PROBE #1	COMP DSCG PROBE #2	FLOW	AMBI HUMID %	RATED	STARTED	START	END	END			1ST 45-55	2ND 225-275	3RD 900-1100	4TH 5000				
0710	Start																			
0710	10.8	61.3	NA	NA	74						2.5		44	230	950	4900	19.5	14	NA	42
0810	11.8	62.2	81.4	NA	72						2.5		45	240	1000	4900	19.5	14	NA	39
0910	12.8	68.5	85.3	NA	70						2.5		45	240	1000	4900	19.5	14	29.75	36
1010	13.8	69.5	88.5	22	69						2.5		45	245	1000	5000	20	14	29.81	37
1110	14.8	74.5	92.1	24	66						2.5		45	245	1000	5000	20	14	29.75	37
1115	Sample																			
1210	15.8	78.1	95.5	28	64						2.3		45	245	1000	5000	20	14	29.63	36
1220	Stop																			
1320	Start																			
1320	15.9	77.8	80.1	24	66						2.5		44	240	1000	5000	20	14	29.75	37
1420	16.9	76.3	82	28	68						2.5		45	245	1000	5000	20	14	29.63	36
1520	17.9	73.2	92.6	26	74						2.5		45	245	1000	5000	20	14	29.69	36

NOTES: 1. Oil full at startup and shutdown.
2. Discharge pressure at 4900 psi at time of startup; 5500 psi fourth stage relief valve leaked over 4900 psi, causing loss of nitrogen to atmosphere. Replaced relief valve while down to repair transformer (1220).
3. At 1218 compressor began to cut off and on rapidly as it did on 17 Oct. At 1220 compressor shut itself off. Problem was again a broken transformer wire due to constant vibration to power panel assembly, causing loss of power. Broken wire was on the same board as the previously broken wire. See recommendations section for operator's suggestion.

RIX COMPRESSOR
4VX BREATHING AIR PACKAGE/230V
ACCEPTANCE TEST DATA

NITROGEN TEST

DATE: 1 November 1995

TIME	METER HOURS	TEMP °F			AMBI HUMID %	CHARGED CYLINDER SIZE		CYLINDER CHARGING INFORMATION			INLET PSIG MAX: 2.5 MIN: 0	CYL FILL TIME	COMPRESSOR CYLINDER STAGES PSI				FLOW RDG	FLOW PSIG	SCFM (Calc)	OIL PRESS PSI
		AMBI PROBE #1	COMP DSCHG PROBE #2	FLOW MAX: 70 MIN: -10		RATED CU FT	PSI	START TIME	END TIME	END PSI			1ST 45-55	2ND 225-275	3RD 900-1100	4TH 5000				
0703	25.9	72.5	82.1	26	99						2.5		44	230	950	4800	20	14	29.69	40
0803	26.9	76.7	94.8	30	91						2.3		45	240	1000	5000	20	14	29.57	37
0903	27.9	80.6	98.7	34	86						2.2		45	245	1000	5000	20	14	29.45	36
1003	28.9	85.8	103.6	40	79						2.2		45	245	1000	5000	20	14	29.27	36
1103	29.9	88.3	105.6	41	80						2.1		45	245	1000	5000	20	14	29.24	36
1120	30.1		105.6	40	80						2.1		45	245	1000	5000	20	14	29.27	36
1120	Stop																			
1256	Start																			
1256	30.1			40	80						2.3		45	245	1000	5000	20	14	29.27	36
1356	31.1	86.4	105.2	42	80						2.3		45	245	1000	5000	20	14	29.21	36
1456	32.1	83.3	100.2	38	91						2.2		45	245	1000	5000	20	14	29.33	36
1556	33.1	81.8	99.7	36	93						2.2		45	245	1000	5000	20	14	29.39	36
1656	34.1	83.0	100.7	36	93						2.2		45	245	1000	5000	20	14	29.39	36
1725	35.5	82.7	100.1	36	94						2.2		45	245	1000	5000	20	14	29.39	36

NOTES: 1. Oil full at startup and shutdown.

NITROGEN TEST

TIME	METER HOURS	TEMP °F			AMBI HUMID %	CHARGED CYLINDER SIZE		CYLINDER CHARGING INFORMATION			INLET PSIG MAX: 2.5 MIN: 0	CYL FILL TIME	COMPRESSOR STAGES PSI				FLOW RDG	FLOW PSIG	SCFM (Calc)	OIL PRESS PSI	
		AMBI PROBE #1	COMP DSCHG PROBE #2	FLOW		RATED	CU FT	PSI	START TIME	END TIME			END PSI	1ST 45-55	2ND 225-275	3RD 900-1100					4TH 5000
0700	17.9	68.1	NA	NA	95						2.5		44	220	950	4500	20	14	NA	44	
0800	18.9	68.9	88.2	22	94						2.5		45	230	1000	5000	20	14	29.81	38	
0900	19.9	70.5	89.9	24	91						2.2		45	245	1000	5000	19.5	14	29.00	36	
1000	20.9	73.2	9.18	26	88						2.3		45	245	1000	5000	19.5	14	28.94	36	
1100	21.9	73	93.3	28	88						2.2		45	245	1000	5000	19.5	14	28.89	36	
1200	22.9	74.2	94.8	28	86						2.1		45	245	1000	5000	19.5	14	28.89	36	
1300	23.9	78.9	98.0	32	79						2.0		45	245	1000	5000	19.5	14	28.77	36	
1400	24.9	79.5	98.5	32	80						2.2		45	245	1000	5000	19.5	14	28.77	36	
1500	25.9	77.4	98.5	32	81						2.2		45	245	1000	5000	19.5	14	28.77	36	

NOTES: 1. Oil full at startup and shutdown.

Appendix A-6

NITROGEN TEST

TIME	METER HOURS	TEMP °F				AMBI HUMID %	CHARGED CYLINDER SIZE		CYLINDER CHARGING INFORMATION			INLET PSIG MAX: 2.5 MIN: 0	CYL FILL TIME	COMPRESSOR STAGES PSI					FLOW RDG	FLOW PSIG	SCFM (Calc)	OIL PRESS PSI
			PROBE #1	COMB DSCHG PROBE #2	FLOW MAX: 70 MIN: -10		RATED CU FT	START PSI	END TIME	END PSI	1ST 45-55			2ND 225-275	3RD 900-1100	4TH 5000						
0557	34.5	72.8	82.4	26	100						2.3			44	240	1000	5000	20	14	29.69	40	
0657	35.5	82.6	99.0	34	97						2.5			45	245	1000	5000	19.5	14	28.71	36	
0757	36.5	84.2	102.9	38	72						2.3			45	245	1000	5000	19.5	14	28.59	36	
0857	37.5	86.4	105.9	42	79						2.3			45	245	1000	5000	19.5	14	28.48	36	
0957	38.5	90.6	107.5	44	81						2.3			45	245	1000	5000	19.5	14	28.42	36	
1004	Sample																					
1024	39.0	92.2	108.1	44	78						2.3			45	245	1000	5000	19.5	14	28.42	36	

NOTES:

- Oil full at startup and shutdown.

AIR TEST

[illegible]

Appendix A-8

AIR TEST

[illegible]

Appendix A-9

AIR TEST

[illegible]

Appendix A-10

AIR TEST

[illegible]

NOTES:

1. Oil full at startup and shutdown.
2. At 0928 OL light came on and compressor shut down. Pressed reset and restarted.

AIR TEST

NOTES: 1. Oil full at startup and shutdown.

NOTES:

1. Oil full at startup and shutdown.
2. During charge compressor shut down when OL light came on; stopped charge and took first reading. Compressor ran approximately 6 minutes and shut down again. Again pressed reset and restarted compressor. It ran for 35 minutes and again OL light came on and compressor shut down. Removed controller cover and, before resetting, 2, 3, 6, and 7 were lit. When pushing reset button light 2 went off and compressor started again. 24 minutes later, while charging, compressor shutdown for fourth time. Cause unknown. Air temperature and oil pressure normal. Only possible cause: unstable power supply to machine or controller failure.

AIR TEST

[illegible]

Appendix A-13

RIX COMPRESSOR
4VX BREATHING AIR PACKAGE/230V
ACCEPTANCE TEST DATA

AIR TEST

DATE: 27 November 1995

TIME	METER HOURS	AMBIENT TEMP.	AMBIENT HUMIDITY	COMPRESSOR INFORMATION						CYL FILL TIME					SCFM (Calc)
				OIL PRESSURE	1ST 45-55	2ND 225-275	3RD 900-1100	4TH 5000	DISCHARGE TEMPERATURE		START TEMPERATURE	START PRESSURE	END TEMPERATURE	END PRESSURE	
0722	85.1	70	78	38	46	245	1000	5000	58.3	30.5	54.8	0	121.5	4725	29.5
0822	86.1	70	78	38	45	240	850	1850	52.3						
0922	87.1	77.5	67	38	45	240	850	1850	56.4						
1014	88.0	80.2	66	38	46	245	1000	5000	58.3	30.6	45	0	115.8	4675	28.8
1114	98.0	80.9	63	36	45	240	850	1850	59.9						
1214	90.0	83	68	36	45	240	850	1850	60.3						
1254	90.7	83	66	36	46	245	1000	5000	61.3	30.5	46.9	0	112.3	4550	28.4
1454	91.7	82	70	36	45	240	850	1850	60.3						
1455	92.7	84	76	36	45	240	850	1850	60.2						
1515	93.0	81	79	36	46	245	95	3400	59.3	20	44.1	500	112.2	3450	28.0

NOTES: 1. Oil full at startup and shutdown.

Memorandum

25 October 1995

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from RIX Model 4VX Compressor,
Test plan 95-14. 1-Hour sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	OMIT	20-22% ²
Nitrogen	100.0%	NONE ²
Argon	OMIT	NONE ²
Carbon Dioxide	OMIT	1000 PPM ²
Total Hydrocarbons ¹	<0.5 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	<0.1 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component	Level	LIMITS
NONE		
C4+	<0.1 PPM	NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.


Glen Deason
Chemist

Memorandum

30 October 1995

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from RIX Model 4VX Compressor,
Test plan 95-14. 25-Hour sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	OMIT	20-22% ²
Nitrogen	100.0%	NONE ²
Argon	OMIT	NONE ²
Carbon Dioxide	OMIT	1000 PPM ²
Total Hydrocarbons ¹	<0.5 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	<0.1 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component	Level	LIMITS
NONE		
C4+	<0.1 PPM	NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.


Glen Deason
Chemist

Memorandum

02 November 1995

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from Rix Model 4VX Compressor
Test. Plan 95-14, 50 Hour Sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	OMIT	20-22% ²
Nitrogen	100.0%	NONE ²
Argon	OMIT	NONE ²
Carbon Dioxide	OMIT	1000 PPM ²
Total Hydrocarbons ¹	<0.5 PPM	25 PPM ¹
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	<0.1 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component	Level	LIMITS
NONE		
C4+	<0.1 PPM	NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.


Glen Deason
Chemist

Memorandum

13 November 1995

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample from Rix Model 4VX Compressor
Test. Plan 95-14, 1 Hour Sample. AM TEST

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	21.0%	20-22% ²
Nitrogen	78.1%	NONE ²
Argon	0.9%	NONE ²
Carbon Dioxide	210 PPM	1000 PPM ²
Total Hydrocarbons ¹	3.7 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	3.7 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component	Level	LIMITS
NONE		
C4+	<0.1 PPM	NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

A handwritten signature in dark ink, appearing to read "Glen Deason", with a stylized flourish at the end.

Glen Deason
Chemist

Memorandum

21 November 1995

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample taken from RIX Model 4VX
Compressor Test. 95-14 Air Test, 25 Hour Sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	21.0%	20-22% ²
Nitrogen	78.1%	NONE ²
Argon	0.9%	NONE ²
Carbon Dioxide	296 PPM	1000 PPM ²
Total Hydrocarbons ¹	3.4 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	3.4 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component	Level	LIMITS
NONE		

C4+

<0.1 PPM

NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.


Glen Deason
Chemist

Memorandum

28 November 1995

To: Dave Sullivan, NEDU

From: Glen Deason, Code 2530

Subject: Analysis of air sample taken from RIX Model 4VX
Compressor Test. 95-14 Air Test, 50 Hour Sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Standard Components

Component	Level	Limit
Oxygen	21.0%	20-22% ²
Nitrogen	78.1%	NONE ²
Argon	0.9%	NONE ²
Carbon Dioxide	345 PPM	1000 PPM ²
Total Hydrocarbons ¹	2.7 PPM	25 PPM ²
Carbon Monoxide	<0.5 PPM	20 PPM ²
Methane	2.7 PPM	1000 PPM ²
Acetone	<0.1 PPM	200 PPM ²
Benzene	<0.1 PPM	1 PPM ²
Chloroform	<0.1 PPM	1 PPM ²
Ethanol	<0.1 PPM	100 PPM ²
Freon 113	<0.1 PPM	100 PPM ²
Freon 11	<0.1 PPM	100 PPM ²
Freon 12	<0.1 PPM	100 PPM ²
Freon 114	<0.1 PPM	100 PPM ²
Isopropyl Alcohol	<0.1 PPM	1 PPM ²
Methanol	<0.1 PPM	10 PPM ²
Methyl Chloroform	<0.1 PPM	30 PPM ²
Methyl Ethyl Ketone	<0.1 PPM	20 PPM ²
Methyl Isobutyl Ketone	<0.1 PPM	20 PPM ²
Methylene Chloride	<0.1 PPM	25 PPM ²
Toluene	<0.1 PPM	20 PPM ²
Trimethyl Benzenes	<0.1 PPM	3 PPM ²
Xylenes	<0.1 PPM	50 PPM ²

Other Components

Component	Level	LIMITS
NONE		

C4+

<0.1 PPM

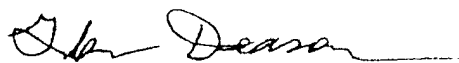
NONE

¹Expressed as methane equivalents.

²Limits taken from Navy Dive Manual; Vol. 2, Rev. 3.

³OSHA Final Rule limits published as of July 1992 (not specified in Navy Dive Manual).

2. The above sample showed no appreciable contamination; all components were within the acceptable range.


Glen Deason
Chemist